PATENT ABSTRACTS OF JAPAN

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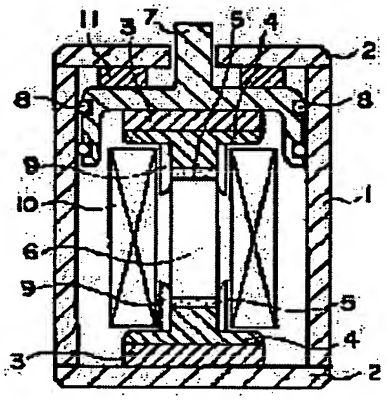
(54) MAGNETOSTRICTIVE VIBRATOR

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a highly efficient magnetostrictive vibrator having a small size and high power and which can be set at desiring resonance frequency.

SOLUTION: A magnetostrictive vibrator has a magnetostrictive rod 6 as a displacement generating member made of a magnetic body having magnetostriction, a movable yoke 7 which is connected with the magnetostrictive rod 6 and can move in the displacement generation direction of the magnetostrictive rod 6, an air-core coil 10 as a driving magnetic field generating means to cause displacement of the magnetostrictive rod 6, and a permanent magnet 3 as a magnetic bias applying means to apply a biased magnetic field to the magnetostrictive rod 6. The resonance frequency can be adjusted by placing an elastic body 5 in series with the magnetostrictive rod 6.



LEGAL STATUS

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* NOTICES *

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CLAIMS

[Claim(s)]
[Claim 1] the variation rate which consists of the magnetic substance which has magnetostriction -- a generating member and said variation rate -- it connects with a generating member -- having -- a variation rate -- the variation rate of a generating member -- with movable moving-part material in a direction In the magnetostriction type vibrator possessing a drive field generating means to generate the drive field for making said displacement generating member produce a variation rate, and a magnetic-bias impression means to impress a bias field to said displacement generating member Magnetostriction type vibrator characterized by building an elastic body in said displacement generating member and serial.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the magnetostriction type vibrator using the magnetic substance which has magnetostriction.
[0002]
[Description of the Prior Art] When magnetostriction impresses an external magnetic field to a certain kind of magnetic substance, it is a phenomenon which deformation produces. Conventionally, to apply this magnetostrictivity to magnetic-machine conversion devices, such as a displacement control actuator, a magnetostriction type trembler, a magnetostriction sensor, a magnetostriction filter, and a supersonic delay line, is tried. Moreover, as a magnetostriction ingredient, nickel radical alloy, the Fe-Co alloy, the ferrite system oxide, etc. are used widely until now. Furthermore, development of the displacement mechanical component in which the minute displacement control of micron order is possible is called for with an advance of instrumentation technology in recent years and development of the precision instrument field. Magnetic-machine conversion device which used magnetostriction too to such a demand is examined. However, the application of the displacement control of micron order is not yet enough as a magnetostriction ingredient which was mentioned above in respect of the point of the absolute magnitude of a variation rate, or a precision controllability. On the other hand, that to which saturation magnetostriction (lambdas) exceeds 1000x10-6 is recently reported by the Ra Beth mold intermetallic compound of a rare earth-iron system, and the expectation for magnetic-machine displacement conversion device using this is growing.
[0003] When applying a magnetostriction ingredient to a device, for example, a magnetostriction type actuator, in order to obtain the absolute magnitude of sufficient variation rate, without causing enlargement of the actuator itself, it is important to raise the conversion efficiency to the variation rate of the external magnetic field, i.e., a drive field, impressed to the displacement generating member produced with the magnetostriction ingredient. The bias field by compressive stress, a permanent magnet, etc. is beforehand impressed to the magnetic substance from such a viewpoint at JP,4-229085,A, and the technique which raises the conversion efficiency between a drive field and the absolute magnitude of a variation rate is indicated.
[0004] Moreover, application of magnetostriction type vibrator is tried, for example as actuators for oscillating control, such as a supersonic machine. In this case, the whole resonance frequency is controlled and it is necessary to make it resonance not take place easily combining the magnetostriction type vibrator which has the resonance frequency of the body which should be carried out excitation, and different resonance frequency from this. It can ask for the resonance frequency (fr) of magnetostriction type vibrator by following the (1) formula.
[0005]
fr=(1/2pi) (g-k/M) 1/2 (1)
Here, it is the weight of the body with which g excites gravitational acceleration and the load rate of a magnetostriction ingredient and M excite k. The load rate (k) of a magnetostriction ingredient is given by following the (2) formula.
[0006]
k=E-A/L (2)
Here, E is [the cross section of a magnetostriction ingredient and L of the Young's modulus of a magnetostriction ingredient and A] the die length of a magnetostriction ingredient.
[0007] (1) The resonance frequency (fr) of a magnetostriction type trembler is a load rate (determined by k and the objective weight (M) to excite.) of a magnetostriction ingredient from a formula. Therefore, when the weight of the body to excite is decided, it is necessary to adjust the load rate of a magnetostriction ingredient for setting it as desired resonance frequency. (2) A formula shows that the load rate of a magnetostriction ingredient is dependent on the ratio (aspect ratio: L/A) of the cross section (A) and die length (L). In order to set resonance frequency to a low frequency side especially, it is necessary to enlarge an aspect ratio. However, the cross section of a magnetostriction ingredient must be enlarged to some extent according to the weight of the body to excite, and the die length of a magnetostriction ingredient must be enlarged to some extent according to the amount of displacement which vibrator needs. Consideration of these points and aspect ratios stops avoiding enlargement of an actuator. Moreover, when the magnetostriction ingredient of a rare earth-iron system is used, and the mechanical strength is taken into consideration, there is a limitation also in enlarging an aspect ratio. This is because it has the description of being weak, in bending stress, although the magnetostriction ingredient of a rare earth-iron system is strong to compressive stress. Therefore, when the magnetostriction ingredient of a rare earth-iron system is used, adjustment of resonance frequency becomes difficult. Thus, in the conventional magnetostriction type vibrator, there is a trouble that it is difficult to set to a desired resonance frequency, especially low frequency side, avoiding enlargement.
[0008]
[Problem(s) to be Solved by the Invention] The purpose of this invention has the enough absolute magnitude of a variation rate, and it is to offer small [which can be set as desired resonance frequency], high power, and efficient magnetostriction type vibrator.
[0009]
[Means for Solving the Problem] The displacement generating member which the magnetostriction type vibrator of this invention becomes from the magnetic substance which has magnetostriction, It connects with said displacement generating member. Moving-part material movable in the displacement direction of a displacement generating member, In the magnetostriction type vibrator possessing a drive field generating means to generate the drive field for making said displacement generating member produce a variation rate, and a magnetic-bias impression means to impress a bias field to said displacement generating member, it is characterized by building an elastic body in said displacement generating member and serial.
[0010] In the magnetostriction type vibrator of this invention, with the elastic body built in the displacement generating member and

the serial, the load rate to which only a displacement generating member is applied can be adjusted, and resonance frequency can be set as a desired value.

[0011]

[Embodiment of the Invention] Hereafter, this invention is further explained to a detail. In this invention, especially the magnetic substance (magnetostriction ingredient) that has the magnetostriction used as a displacement generating member is not limited. For example, although nickel radical alloy widely known from the former, a Fe-aluminum alloy, a ferrite system oxide, etc. can be used, a bigger thing has the viewpoint of the miniaturization of the magnetostriction type vibrator obtained, and a high increase in power to a more desirable saturation magnetostriction value (lambdas). Therefore, the giant magnetostrictive alloy which consists of a rare earth-iron system Ra Beth mold intermetallic compound can be used suitably. The presentation with which it is specifically satisfied of RFex (R is a kind of rare earth elements and 1.5<=X<=2.5 at least) is mentioned. In addition, two or more sorts of combination, such as Tb-Dy, such as La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu, and Tb-Ho, Tb-Pr, Sm-Yb, Tb-Dy-Ho, Tb-Dy-Pr, and Tb-Pr-Ho, is illustrated as desirable rare earth elements (R element).

[0012] In the giant magnetostrictive alloy of a rare earth-iron system, a part of Fe may be permuted by Co. If a part of Fe is permuted by Co, corrosion resistance is improvable while being able to improve the magnetostriction property in low temperature. However, since there is an inclination which causes the fall of a magnetostriction property conversely when there are too many amounts of Co permuted by Fe, it is desirable that the amount of permutations by Co is less than [of Fe / 95at%].

[0013] In this giant magnetostrictive alloy, a part of Fe may be permuted from Mn. If a part of Fe is permuted from Mn, the magnetic anisotropy of the rare earth atom in a giant magnetostrictive alloy can change, and the magnetostriction property which was excellent not only in a high field but the low field can be acquired. However, since there is a possibility that the Curie temperature of a giant magnetostrictive alloy may fall and a magnetostriction property may be spoiled when there are too many amounts of Mn permuted by Fe, it is desirable that the amount of permutations by Mn is less than [of Fe / 50at%]. Moreover, a part of Fe may be further permuted if needed by nickel, Mg, aluminum, Ga, Zn, V, Zr, Hf, Ti, Nb, Cu, Ag, Sn, Mo, Cr, Ta, Pd, In, Sb, Ir, Pt, Au, Pb, Si, germanium, B, etc. from a viewpoint of improvement, such as material strength of a giant magnetostrictive alloy, corrosion resistance, and saturation magnetostriction. In this case, it is desirable that the amount of permutations by these metallic elements and Mn is less than [of Fe / 50at%]. Furthermore, R(Fe1-a Mna) x A more desirable material property is acquired by satisfying the value of a=0.01-0.3 in an empirical formula. If the amount exceeding 50at(s)% of Fe is permuted from these metallic elements and Mn, it will become the factor of property degradation, such as a fall of the amount of magnetostriction.

[0014] Although that by which the displacement generating member generally fabricated the magnetostriction ingredient to the rod is used, especially the configuration is not limited. For example, the rod of various configurations, such as the shape of cylindrical, cylindrical, a prismatic form, and a laminating, can be used. The laminating of the part which carried out vertical division to the longitudinal direction of a rod is carried out to the shape of a laminating, for example, it is made the shape of a cylinder here. When setting the oscillation frequency of magnetostriction type vibrator as several kHz or more, the thing of the skin effect, and the shape of cylindrical from a viewpoint of eddy current loss or a laminating is desirable.

[0015] In this invention, movable moving-part material is connected to the end side of a displacement generating member in the displacement direction. Other members, such as a magnetic-bias impression means to mention later if needed, and an elastic body, may be made to intervene between a displacement generating member and moving-part material. Especially the configuration of this moving-part material is not limited.

[0016] In this invention, the air cored coil prepared, for example in the periphery of a displacement generating member is used as a drive field generating means to generate the drive field for making a displacement generating member produce a variation rate. When the die length of the magnetostriction rod which is a displacement generating member is set to Lm, as for the die length Lc of this air cored coil, it is desirable to consider as the range of 0.5 Lm<Lc<2Lm. It becomes difficult to impress to homogeneity the drive field which an air cored coil forms to a magnetostriction rod as the die length Lc of an air cored coil is 0.5 or less Lms. On the other hand, if the die length Lc of an air cored coil is set to 2 or more Lms, although a drive field can be efficiently impressed to a magnetostriction rod, enlargement of the whole magnetostriction type vibrator is caused.

[0017] If only one thing of a multilayer uniform volume is used as an air cored coil, structure will become simple most. However, in the air cored coil of multilayer uniform volume structure, there is an inclination for the drive field formed to come to have in a core the uneven spatial distribution that it is large and small at both ends. And in case the control current is supplied to an air cored coil, it will be necessary to rationalize values, such as direct current resistance and an inductance, from the constraint by the side of a power source. On the other hand, if parallel connection of these is carried out to a power source using two or more air cored coils divided along with the longitudinal direction of a magnetostriction rod, or two or more air cored coils by which the multiplex volume was carried out in the direction of a laminating, the spatial distribution of the drive field formed can be equalized. Moreover, if an air cored coil is directly stuck to a magnetostriction rod and is twisted around it, a drive field can be efficiently impressed to a magnetostriction rod. However, as for the viewpoint of dependability to an air cored coil, it is desirable to make it a magnetostriction rod and non-contact.

[0018] In this invention, the permanent magnet magnetized, for example in the thickness direction is prepared in the both ends of a magnetostriction rod as a magnetic-bias impression means to impress a bias field to a displacement generating member. Direct-current magnetic bias is impressed to a magnetostriction rod with these permanent magnets. With such a configuration, it becomes possible to generate the variation rate corresponding to the positive/negative of the control current supplied to an air cored coil in a magnetostriction rod. It is desirable to use a Sm-Co system alloy, a Nd-Fe-B system alloy, etc. from a viewpoint of a miniaturization of the magnetostriction type vibrator obtained as a permanent magnet.

[0019] The point which builds an elastic body in a displacement generating member and a serial has the characteristic configuration of this invention. here -- a serial -- a variation rate -- the fixed end of the magnetostriction type vibrator which is fixing the generating member, and the movable end of magnetostriction type vibrator, i.e., a variation rate, -- the variation rate connected to the generating member -- the variation rate of a generating member -- between the edges of moving-part material movable in a direction -- an equal circuit -- seeing -- a variation rate -- it means that the generating member and the elastic body are inserted into a serial. Therefore, especially arrangement with a displacement generating member and an elastic body is not restricted. Moreover, an elastic body may be prepared in the both ends of a magnetostriction rod, and may be prepared only in an end.

[0020] Especially an elastic body is not limited, for example, can use a pan spring, a coil spring or natural rubber, and synthetic rubber. However, in a pan spring or a coil spring, since there is a possibility that friction and parasitic oscillation may arise, it is desirable to use natural rubber and synthetic rubber from the point that a uniform vibration is obtained. As rubber, what has the standard degree of hardness Hs (JIS A) in the range of 30-90 is desirable. More specifically, synthetic rubber, such as fluorine system rubber, such as a Viton, silicone rubber, styrol system rubber, nitril system rubber, butyl system rubber, and chloroprene system rubber, is mentioned. Moreover, mechanical shakiness can be absorbed when rubber is used as an elastic body. Furthermore, effect of

the machining precision of the configuration member of magnetostriction type tremblers, such as a displacement generating member, can be lessened, and the chipping (lack) of a displacement generating member can also be prevented.
[0021] In the magnetostriction type vibrator of this invention, since the elastic body is prepared in the displacement generating member and the serial, the load rate to which only a displacement generating member is applied with the quality of the material and the configuration of an elastic body can be adjusted irrespective of the aspect ratio of a displacement generating member. Therefore, resonance frequency can be set as a desired value, avoiding enlargement of the whole magnetostriction type vibrator.
[0022]
[Example] Hereafter, the example of this invention is explained with reference to a drawing. Drawing 1 is drawing of longitudinal section showing an example of the magnetostriction type vibrator concerning this invention. In drawing 1 , the end of the cylindrical container 1 is stopped by the holddown member 2. Inside this cylindrical container 1, the magnetostriction rod 6 which consists of a permanent magnet 3, fixed York 4, an elastic body 5, and the magnetic substance that has magnetostriction, an elastic body 5, fixed York 4, a permanent magnet 3, and movable York 7 are formed one by one on the holddown member 2. O ring 8 of two trains is formed between movable York 7 and the cylindrical container 1. Moreover, the guide 9 is attached in each fixed York 4. Furthermore, the air cored coil 10 is formed in the periphery of the magnetostriction rod 6.
[0023] The predetermined direct-current bias field is impressed to the magnetostriction rod 6 which is a displacement generating member through fixed York 4 from the permanent magnet 3 of both ends. And if the control current is supplied to an air cored coil 10, corresponding to the positive/negative, a variation rate will occur to the magnetostriction rod 1. Consequently, the magnetostriction rod 1 is displaced along with a guide 9. In addition, bending stress joins the magnetostriction rod 6 with O ring 8 between movable York 7 and the cylindrical container 1.
[0024] In the magnetostriction type vibrator of this invention, since the elastic body 5 is formed in the both ends of the magnetostriction rod 6 at the serial, the load rate over which only the magnetostriction rod 1 is covered can be adjusted, and the resonance frequency can be set as a desired value.
[0025] Drawing 2 is drawing of longitudinal section showing other examples of the magnetostriction type vibrator concerning this invention. In drawing 2 , a holddown member 2 is formed also in the other end side of the cylindrical container 1, and the elastic body 11 is formed between this holddown member 2 and movable York 7. Compressive stress is beforehand impressed to the magnetostriction rod 6 by such configuration. In addition, this elastic body 11 is seen in an equal circuit, and does not have the magnetostriction rod 6 and a serial. The other configuration is the same as that of the magnetostriction type vibrator shown in drawing 1 R> 1.
[0026] Next, the magnetostriction type vibrator (c) of the same configuration as drawing 2 was produced except not preparing an elastic body at all at a serial to the same magnetostriction type vibrator (b) of a configuration as drawing 2 , and the magnetostriction rod 6 except having formed the elastic body 5 at the serial only at the end of the magnetostriction type vibrator (a) of drawing 2 which formed elastic bodies 5 and 5 in the serial to the both ends of the magnetostriction rod 6, and the magnetostriction rod 6.
[0027] here -- a variation rate -- as the magnetostriction rod which is a generating member -- Tb0.5 Dy0.5 1.93 (Fe0.9 Mn0.1) -- the with a die length [the outer diameter of 12mm and die length of 20mm] which consist of a giant magnetostrictive alloy to which crystal orientation of the presentation was had and carried out thing was used. As an elastic body 5, the silicone rubber with an outer diameter [of 12mm] and a thickness of 1mm of standard degree-of-hardness Hs=50 was used. Moreover, the 250kg load was beforehand impressed to the magnetostriction rod 6 with the elastic body 11.
[0028] And about each magnetostriction type vibrator, the constant voltage of **10V was supplied to the air cored coil 10, and it investigated frequency dependent [of the amount of displacement]. This result is shown in drawing 3 . The peak location in drawing 3 is equivalent to the resonance frequency of each magnetostriction type vibrator.
[0029] According to the existence and the number of a magnetostriction rod and the elastic body (silicone rubber) built in a serial, three kinds of resonance frequency of magnetostriction type vibrator (a) - (c) is changing so that clearly from drawing 3 . As compared with the magnetostriction type vibrator of (c) which has not prepared the elastic body, resonance frequency shifted to the low frequency side in the magnetostriction type vibrator of (b) which prepared the elastic body only in the end of a magnetostriction rod, and, specifically, resonance frequency has shifted to the both ends of a magnetostriction rod further with the magnetostriction type vibrator of elastic body ****** (a) to the low frequency side. Therefore, by building an elastic body in a magnetostriction rod and a serial shows that the load rate over which only a magnetostriction rod is covered is adjusted, and the resonance frequency can be set as a desired value. In addition, as for drawing 3 , even if it builds an elastic body in a magnetostriction rod at a serial, in a low frequency field, the absolute value of the amount of displacement also shows falling a little.
[0030] The configuration of the magnetostriction type vibrator of this invention can consider not only a thing but the various modifications shown in drawing 1 and drawing 2 . These modifications are shown in drawing 4 , drawing 5 , and drawing 6 . Although drawing 4 R> 4 has a configuration similar to drawing 1 , sequential arrangement of a permanent magnet 3, an elastic body 5, fixed York 4, the magnetostriction rod 6, fixed York 4, an elastic body 5, and the permanent magnet 3 is carried out toward movable York 7 from a holddown member 2.
[0031] Although drawing 5 has a configuration similar to drawing 2 , sequential arrangement of an elastic body 5, a permanent magnet 3, fixed York 4, the magnetostriction rod 6, fixed York 4, a permanent magnet 3, and the elastic body 5 is carried out toward movable York 7 from a holddown member 2.
[0032] If it sees in an equal circuit and the conditions of a serial are fulfilled as shown in drawing 4 and drawing 5 , especially arrangement with the magnetostriction rod 6 and an elastic body 5 will not be restricted. Drawing 6 is an example of a configuration in the case of needing the big amount of displacement, and arranges two magnetostriction rods 6 and 6 to a serial through an elastic body 5, a permanent magnet 3, and an elastic body 5. The other configuration is the same as that of drawing 2 R> 2. In this case, it is desirable to form a guide 9 also in both connection section so that two magnetostriction rods 6 and 6 may not cause an imperfect alignment.
[0033]
[Effect of the Invention] As explained in full detail above, according to this invention, small [which can be set as desired resonance frequency], high power, and efficient magnetostriction type vibrator can be offered, and a so-called size has the industrial value.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Drawing of longitudinal section showing an example of the magnetostriction type vibrator concerning this invention.
[Drawing 2] Drawing of longitudinal section showing other examples of the magnetostriction type vibrator concerning this invention.
[Drawing 3] The property Fig. showing frequency dependent [of the amount of displacement] about the magnetostriction type vibrator shown in drawing 2 .
[Drawing 4] Drawing of longitudinal section showing the modification of the magnetostriction type vibrator concerning this invention.

[Drawing 5] Drawing of longitudinal section showing other modifications of the magnetostriction type vibrator concerning this invention.
[Drawing 6] Drawing of longitudinal section concerning this invention in which that it is only serious shows the magnetostriction type vibrator of business.
[Description of Notations]
1 [-- Fixed York, 5 / -- An elastic body, 6 / -- A magnetostriction rod, 7 / -- Movable York, 8 / -- An O ring, 9 / -- A guide, 10 / -- An air cored coil, 11 / -- Elastic body.] -- A cylindrical container, 2 -- A holddown member, 3 -- A permanent magnet, 4

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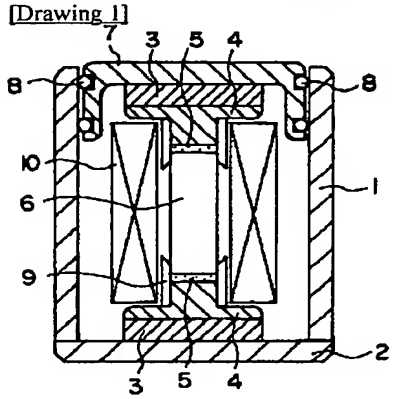
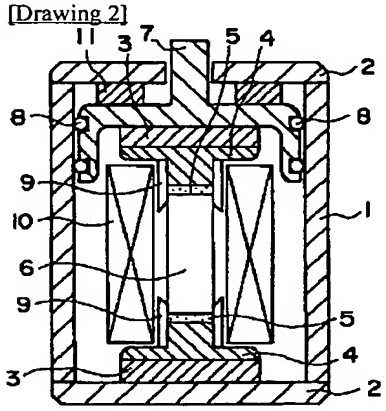
DRAWINGS

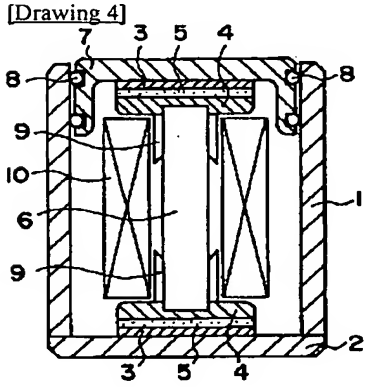
[Drawing 1]



[Drawing 2]



[Drawing 4]



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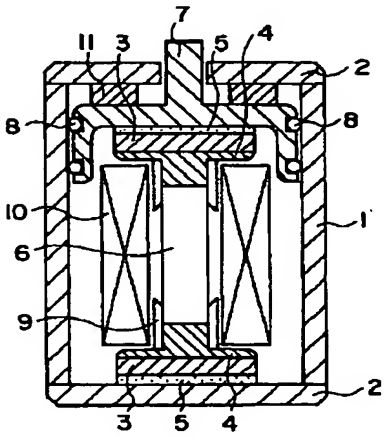
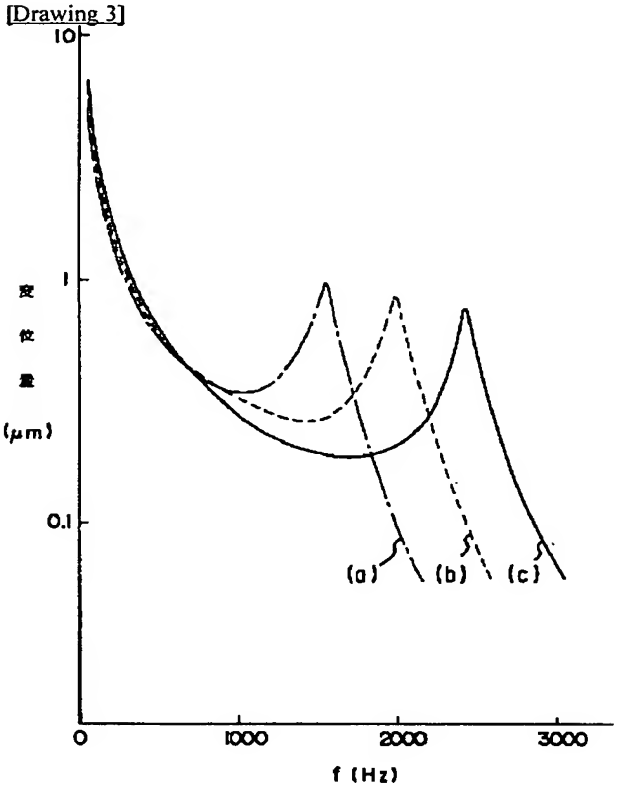
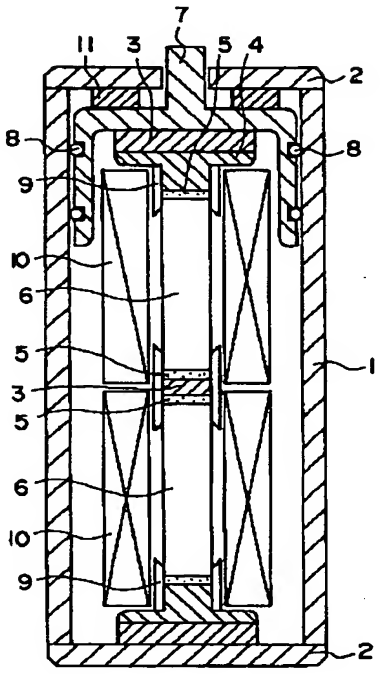


[Drawing 3]



[Drawing 6]



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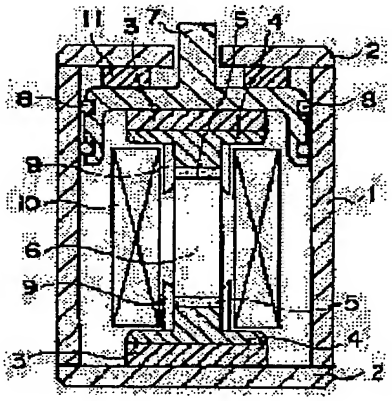

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Ｈ０２Ｎ　2/00			Ｈ０２Ｎ　2/00	Ｄ	

審査請求　未請求　請求項の数１　ＯＬ　（全６頁）

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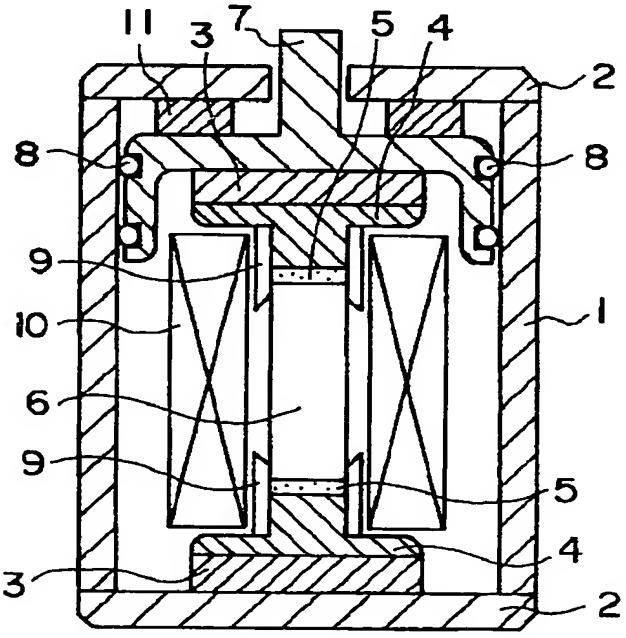
(74)代理人　弁理士　鈴江　武彦

(54)【発明の名称】　磁歪式振動子

(57)【要約】
【目的】　小型でかつ所望の共振周波数に設定可能な大出力、高効率の磁歪式振動子を提供する。
【構成】　磁歪を有する磁性体からなる変位発生部材としての磁歪ロッド６と、磁歪ロッド６に接続され、磁歪ロッド６の変位発生方向に移動可能な可動ヨーク７と、磁歪ロッド６に変位を生じさせるための駆動磁界発生手段としての空心コイル１０と、磁歪ロッド６にバイアス磁界を印加する磁気バイアス印加手段としての永久磁石３とを有し、磁歪ロッド６と直列に弾性体５を配置することにより、共振周波数を調整する。



【特許請求の範囲】
【請求項１】　磁歪を有する磁性体からなる変位発生部材と、前記変位発生部材に接続され、変位発生部材の変位方向に移動可能な可動部材と、前記変位発生部材に変位を生じさせるための駆動磁界を発生する駆動磁界発生手段と、前記変位発生部材にバイアス磁界を印加する磁気バイアス印加手段とを具備した磁歪式振動子において、前記変位発生部材と直列に弾性体を内蔵したことを特徴とする磁歪式振動子。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、磁歪を有する磁性体を用いた磁歪式振動子に関する。
【０００２】
【従来の技術】磁歪は、ある種の磁性体に外部磁場を印加した際に変形が生じる現象である。従来より、この磁歪現象を変位制御アクチュエータ、磁歪式振動子、磁歪センサ、磁歪フィルタ、超音波遅延線などの磁気ー機械変換デバイスへ応用することが試みられている。またこれまで、磁歪材料としてはＮｉ基合金、Ｆｅ－Ｃｏ合金、フェライト系酸化物などが広く用いられている。さらに、近年の計測工学の進歩および精密機械分野の発展に伴い、ミクロンオーダーの微小変位制御が可能な変位駆動部の開発が求められている。このような要求に対してやはり磁歪を利用した磁気ー機械変換デバイスが検討されている。しかし、上述したような磁歪材料は、ミクロンオーダーの変位制御の用途では、変位の絶対量の点でも精密制御性の点でもいまだ十分ではない。一方、最近になって希土類ー鉄系のラーベス型金属間化合物で飽和磁歪（λｓ）が１０００×１０$^{-6}$を超えるものが報告されており、これを用いた磁気ー機械変位変換デバイスへの期待が高まっている。
【０００３】磁歪材料をデバイス例えば磁歪式アクチュエータに応用する場合、アクチュエータ自体の大型化を招くことなく十分な変位の絶対量を得るためには、磁歪材料で作製された変位発生部材に印加される外部磁場すなわち駆動磁界の変位への変換効率を向上させることが重要である。このような観点から特開平４－２２９０８５号公報には、圧縮応力や永久磁石などによるバイアス磁界を磁性体に予め印加して、駆動磁界と変位の絶対量との間の変換効率を高める技術が開示されている。
【０００４】また、例えば超音波加工機などの振動制御用アクチュエータとして磁歪式振動子の応用が試みられている。この場合、加振すべき物体の共振周波数と、これとは異なる共振周波数を有する磁歪式振動子とを組み合わせて、全体の共振周波数を制御し、容易に共振が起こらないようにする必要がある。磁歪式振動子の共振周波数（ｆｒ）は下記（１）式で求めることができる。
【０００５】
$$fr = (1/2\pi)\ (g \cdot k/M)^{1/2} \qquad (1)$$
ここで、ｇは重力加速度、ｋは磁歪材料のバネ定数、Ｍは加振する物体の重量である。磁歪材料のバネ定数（ｋ）は下記（２）式で与えられる。
【０００６】
$$k = E \cdot A/L \qquad (2)$$
ここで、Ｅは磁歪材料のヤング率、Ａは磁歪材料の断面積、Ｌは磁歪材料の長さである。
【０００７】（１）式より磁歪式振動子の共振周波数（ｆｒ）は磁歪材料のバネ定数（ｋおよび加振する物体の重量（Ｍ）によって決定される。したがって、加振する物体の重量が決まっている場合に、所望の共振周波数に設定するには磁歪材料のバネ定数を調整する必要がある。（２）式より磁歪材料のバネ定数は断面積（Ａ）と長さ（Ｌ）との比（アスペクト比：Ｌ／Ａ）に依存することがわかる。特に、共振周波数を低周波数側に設定するには、アスペクト比を大きくする必要がある。しかし、磁歪材料の断面積は加振する物体の重量に応じてある程度大きくし、磁歪材料の長さは振動子の必要とする変位量に応じてある程度大きくしなければならない。これらの点とアスペクト比とを考慮すると、アクチュエータの大型化が避けられなくなる。また、希土類ー鉄系の磁歪材料を用いた場合、その機械的強度を考慮するとアスペクト比を大きくするにも限界がある。これは、希土類ー鉄系の磁歪材料は圧縮応力には強いが、曲げ応力には弱いという特徴を有しているためである。したがって、希土類ー鉄系の磁歪材料を用いた場合には、共振周波数の調整が困難になる。このように従来の磁歪式振動子では、大型化を避けながら、所望の共振周波数、特に低周波数側に設定することが困難であるという問題点がある。
【０００８】
【発明が解決しようとする課題】本発明の目的は、変位の絶対量が十分で、所望の共振周波数に設定可能な小型、大出力、高効率の磁歪式振動子を提供することにある。
【０００９】
【課題を解決するための手段】本発明の磁歪式振動子は、磁歪を有する磁性体からなる変位発生部材と、前記変位発生部材に接続され、変位発生部材の変位方向に移動可能な可動部材と、前記変位発生部材に変位を生じさせるための駆動磁界を発生する駆動磁界発生手段と、前記変位発生部材にバイアス磁界を印加する磁気バイアス印加手段とを具備した磁歪式振動子において、前記変位発生部材と直列に弾性体を内蔵したことを特徴とするものである。
【００１０】本発明の磁歪式振動子においては、変位発生部材と直列に内蔵された弾性体により、変位発生部材のみかけのバネ定数を調整することができ、共振周波数を所望の値に設定できることができる。
【００１１】

【発明の実施の形態】以下、本発明をさらに詳細に説明する。本発明において、変位発生部材として用いられる磁歪を有する磁性体（磁歪材料）は特に限定されない。例えば、従来から広く知られているＮｉ基合金、Ｆｅ－Ａｌ合金、フェライト系酸化物などを用いることができるが、得られる磁歪式振動子の小型化および高出力化の観点から、飽和磁歪値（λｓ）が大きなものほど好ましい。したがって、希土類－鉄系ラーベス型金属間化合物からなる超磁歪合金を好適に用いることができる。具体的にはＲＦｅｘ（Ｒは少なくとも一種の希土類元素、１．５≦Ｘ≦２．５）を満足する組成が挙げられる。なお、好ましい希土類元素（Ｒ元素）として、例えばＬａ、Ｃｅ、Ｐｒ、Ｎｄ、Ｐｍ、Ｓｍ、Ｅｕ、Ｇｄ、Ｔｂ、Ｄｙ、Ｈｏ、Ｅｒ、Ｔｍ、Ｙｂ、Ｌｕなど、およびＴｂ－Ｄｙ、Ｔｂ－Ｈｏ、Ｔｂ－Ｐｒ、Ｓｍ－Ｙｂ、Ｔｂ－Ｄｙ－Ｈｏ、Ｔｂ－Ｄｙ－Ｐｒ、Ｔｂ－Ｐｒ－Ｈｏなど２種以上の組み合わせが例示される。

【００１２】希土類－鉄系の超磁歪合金においては、Ｆｅの一部をＣｏで置換してもよい。Ｆｅの一部をＣｏで置換すると、低温での磁歪特性を向上できるとともに耐食性を改善できる。ただし、Ｆｅと置換されるＣｏの量が多すぎると、逆に磁歪特性の低下を招く傾向があるため、Ｃｏによる置換量がＦｅの９５ａｔ％以下であることが好ましい。

【００１３】この超磁歪合金においては、Ｆｅの一部をＭｎで置換してもよい。Ｆｅの一部をＭｎで置換すると、超磁歪合金中の希土類原子の磁気異方性が変化し、高磁界のみならず低磁界において優れた磁歪特性を得ることができる。ただし、Ｆｅと置換されるＭｎの量が多すぎると、超磁歪合金のキュリー温度が低下し、磁歪特性が損なわれるおそれがあるので、Ｍｎによる置換量がＦｅの５０ａｔ％以下であることが好ましい。また、超磁歪合金の材料強度、耐食性、飽和磁歪などの向上の観点から、必要に応じてＦｅの一部をさらにＮｉ、Ｍｇ、Ａｌ、Ｇａ、Ｚｎ、Ｖ、Ｚｒ、Ｈｆ、Ｔｉ、Ｎｂ、Ｃｕ、Ａｇ、Ｓｎ、Ｍｏ、Ｃｒ、Ｔａ、Ｐｄ、Ｉｎ、Ｓｂ、Ｉｒ、Ｐｔ、Ａｕ、Ｐｂ、Ｓｉ、Ｇｅ、Ｂなどで置換してもよい。この場合、これらの金属元素およびＭｎによる置換量がＦｅの５０ａｔ％以下であることが好ましい。さらに、Ｒ（$Fe_{1-a}Mn_a$）ｘの組成式においてａ＝０．０１～０．３の値を満足することでより好ましい材料特性が得られる。Ｆｅの５０ａｔ％を超える量がこれらの金属元素およびＭｎで置換されると、磁歪量の低下などの特性劣化の要因となる。

【００１４】変位発生部材は一般的に磁歪材料をロッドに成形したものが用いられるが、その形状は特に限定されない。例えば、円柱状、円筒状、角柱状、積層状などの各種形状のロッドを用いることができる。ここで積層状とは、ロッドの長手方向に縦割りした部分を積層して例えば円柱状にしたものである。磁歪式振動子の振動周波数を数ｋＨｚ以上に設定する場合には、表皮効果、渦電流損失の観点から円筒状または積層状のものが好ましい。

【００１５】本発明において、変位発生部材の一端側には、その変位方向に移動可能な可動部材が接続されている。変位発生部材と可動部材との間には、必要に応じて後述する磁気バイアス印加手段や弾性体などの他の部材を介在させてもよい。この可動部材の形状は、特に限定されない。

【００１６】本発明において、変位発生部材に変位を生じさせるための駆動磁界を発生する駆動磁界発生手段としては、例えば変位発生部材の外周に設けられた空心コイルが用いられる。この空心コイルの長さＬｃは、変位発生部材である磁歪ロッドの長さをＬｍとしたとき、

０．５Ｌｍ＜Ｌｃ＜２Ｌｍ

の範囲とすることが好ましい。空心コイルの長さＬｃが０．５Ｌｍ以下であると、磁歪ロッドに対して空心コイルが形成する駆動磁界を均一に印加することが困難となる。一方、空心コイルの長さＬｃが２Ｌｍ以上になると磁歪ロッドに駆動磁界を効率よく印加できるものの、磁歪式振動子全体の大型化を招く。

【００１７】空心コイルとしては多層一様巻きのものを１個だけ用いれば最も構造が単純になる。ただし、多層一様巻き構造の空心コイルでは、形成される駆動磁界が中心部で大きく両端部で小さいという不均一な空間分布をもつようになる傾向がある。しかも、制御電流を空心コイルに供給する際、電源側の制約から直流抵抗、インダクタンスなどの値を適正化する必要が生じる。これに対して、磁歪ロッドの長手方向に沿って分割された複数の空心コイル、または積層方向に多重巻きされた複数の空心コイルを用い、これらを電源に並列接続すれば、形成される駆動磁界の空間分布を均一化することができる。また、空心コイルを磁歪ロッドに直接密着させて巻き付ければ、磁歪ロッドへ駆動磁界を効率よく印加できる。ただし、信頼性の観点から、空心コイルは磁歪ロッドと非接触にすることが好ましい。

【００１８】本発明において、変位発生部材にバイアス磁界を印加する磁気バイアス印加手段としては、例えば厚み方向に着磁された永久磁石を磁歪ロッドの両端に設ける。これらの永久磁石により磁歪ロッドに対して直流磁気バイアスが印加される。このような構成では、磁歪ロッドにおいて空心コイルに供給される制御電流の正負に対応した変位を発生させることが可能となる。永久磁石としては、得られる磁歪式振動子の小型化の観点から、Ｓｍ－Ｃｏ系合金やＮｄ－Ｆｅ－Ｂ系合金などを用いることが好ましい。

【００１９】本発明の特徴的な構成は、変位発生部材と直列に弾性体を内蔵する点にある。ここで、直列とは、変位発生部材を固定している磁歪式振動子の固定端と、磁歪式振動子の可動端すなわち変位発生部材に接続され

た変位発生部材の変位方向に移動可能な可動部材の端部との間に、等価回路で見て、変位発生部材と弾性体とが直列に挟まれていることを意味する。したがって、変位発生部材と弾性体との配置は特に制限されない。また、弾性体は磁歪ロッドの両端に設けてもよいし、一端にのみ設けてもよい。

【００２０】弾性体は特に限定されず、例えば皿バネやコイルスプリング、または天然ゴムや合成ゴムを用いることができる。ただし、皿バネやコイルスプリングでは摩擦や寄生振動が生じるおそれがあるため、均一な振動が得られる点から天然ゴムや合成ゴムを用いることが好ましい。ゴムとしては、標準硬度Ｈｓ（ＪＩＳ　Ａ）が３０～９０の範囲にあるものが好ましい。より具体的には、バイトンなどのフッ素系ゴム、シリコーンゴム、スチロール系ゴム、ニトリル系ゴム、ブチル系ゴム、クロロプレン系ゴムなどの合成ゴムが挙げられる。また、弾性体としてゴムを用いた場合、機械的ながたつきを吸収することができる。さらに、変位発生部材などの磁歪式振動子の構成部材の機械加工精度の影響を少なくし、変位発生部材のチッピング（欠け）を防止することもできる。

【００２１】本発明の磁歪式振動子では、変位発生部材と直列に弾性体を設けているので、変位発生部材のアスペクト比にかかわらず、弾性体の材質や形状によって変位発生部材のみかけのバネ定数を調整することができる。したがって、磁歪式振動子全体の大型化を避けながら、共振周波数を所望の値に設定できる。

【００２２】

【実施例】以下、本発明の実施例を図面を参照して説明する。図１は本発明に係る磁歪式振動子の一例を示す縦断面図である。図１において、円筒型容器１の一端は固定部材２で封じられている。この円筒型容器１の内部には固定部材２上に永久磁石３、固定ヨーク４、弾性体５、磁歪を有する磁性体からなる磁歪ロッド６、弾性体５、固定ヨーク４、永久磁石３および可動ヨーク７が順次設けられている。可動ヨーク７と円筒型容器１との間には２列のＯリング８が設けられている。また、それぞれの固定ヨーク４にはガイド９が取付けられている。さらに、磁歪ロッド６の外周には空心コイル１０が設けられている。

【００２３】変位発生部材である磁歪ロッド６には両端の永久磁石３から固定ヨーク４を介して所定の直流バイアス磁界が印加されている。そして、空心コイル１０に制御電流を供給すると、その正負に対応して磁歪ロッド１に変位が発生する。この結果、磁歪ロッド１はガイド９に沿って変位する。なお、可動ヨーク７と円筒型容器１との間のＯリング８により、磁歪ロッド６には曲げ応力が加わらないようになっている。

【００２４】本発明の磁歪式振動子では、磁歪ロッド６の両端に弾性体５を直列に設けているので、磁歪ロッド１のみかけのバネ定数を調整することができ、その共振周波数を所望の値に設定できる。

【００２５】図２は本発明に係る磁歪式振動子の他の例を示す縦断面図である。図２においては、円筒型容器１の他端側にも固定部材２が設けられ、この固定部材２と可動ヨーク７との間に弾性体１１が設けられている。このような構成により磁歪ロッド６に予め圧縮応力を印加している。なお、この弾性体１１は等価回路で見て、磁歪ロッド６と直列になっていない。それ以外の構成は図１に示した磁歪式振動子と同様である。

【００２６】次に、磁歪ロッド６の両端に直列に弾性体５、５を設けた図２の磁歪式振動子（ａ）、磁歪ロッド６の一端にのみ直列に弾性体５を設けた以外は図２と同じ構成の磁歪式振動子（ｂ）、磁歪ロッド６に直列に弾性体を全く設けない以外は図２と同じ構成の磁歪式振動子（ｃ）を作製した。

【００２７】ここで、変位発生部材である磁歪ロッドとしては、$Tb_{0.5}Dy_{0.5}(Fe_{0.9}Mn_{0.1})_{1.93}$ なる組成を有し、結晶配向させた超磁歪合金からなる、外径１２ｍｍ、長さ２０ｍｍのものを用いた。弾性体５としては、外径１２ｍｍ、厚さ１ｍｍの標準硬度Ｈｓ＝５０のシリコーンゴムを使用した。また、弾性体１１により、磁歪ロッド６に予め２５０ｋｇの負荷を印加した。

【００２８】そして、各磁歪式振動子について、空心コイル１０に±１０Ｖの定電圧を供給して、変位量の周波数依存性を調べた。この結果を図３に示す。図３におけるピーク位置が各磁歪式振動子の共振周波数に相当する。

【００２９】図３から明らかなように、磁歪ロッドと直列に内蔵される弾性体（シリコーンゴム）の有無および個数に応じて、３種類の磁歪式振動子（ａ）～（ｃ）の共振周波数が変化している。具体的には、弾性体を設けていない（ｃ）の磁歪式振動子と比較して、磁歪ロッドの一端にのみ弾性体を設けた（ｂ）の磁歪式振動子では共振周波数が低周波側へシフトし、磁歪ロッドの両端に弾性体設けた（ａ）の磁歪式振動子では共振周波数がさらに低周波側へシフトしている。したがって、磁歪ロッドと直列に弾性体を内蔵することにより、磁歪ロッドのみかけのバネ定数を調整して、その共振周波数を所望の値に設定できることがわかる。なお、図３からは、磁歪ロッドに直列に弾性体を内蔵しても、低周波数領域において変位量の絶対値が若干低下するにすぎないこともわかる。

【００３０】本発明の磁歪式振動子の構成は図１および図２に示したものに限らず、種々の変形例が考えられる。これらの変形例を図４、図５および図６に示す。図４は図１と類似の構成を有するが、固定部材２から可動ヨーク７へ向かって、永久磁石３、弾性体５、固定ヨーク４、磁歪ロッド６、固定ヨーク４、弾性体５、永久磁石３を順次配置したものである。

【００３１】図５は図２と類似の構成を有するが、固定部材２から可動ヨーク７へ向かって、弾性体５、永久磁石３、固定ヨーク４、磁歪ロッド６、固定ヨーク４、永久磁石３、弾性体５を順次配置したものである。

【００３２】図４及び図５に示されるように、等価回路で見て直列という条件を満たしていれば、磁歪ロッド６と弾性体５との配置は特に制限されない。図６は、大きな変位量を必要とする場合の構成例であり、２個の磁歪ロッド６、６を弾性体５、永久磁石３および弾性体５を介して直列に配置したものである。それ以外の構成は図２と同様である。この場合、２個の磁歪ロッド６、６が軸ずれを起こさないように、両者の連結部にもガイド９を設けることが好ましい。

【００３３】

【発明の効果】以上詳述したように本発明によれば、所望の共振周波数に設定可能な小型、大出力、高効率の磁歪式振動子を提供することができ、その工業的価値は大なるものがある。

【図面の簡単な説明】

【図１】本発明に係る磁歪式振動子の一例を示す縦断面図。

【図２】本発明に係る磁歪式振動子の他の例を示す縦断面図。

【図３】図２に示す磁歪式振動子について変位量の周波数依存性を示す特性図。

【図４】本発明に係る磁歪式振動子の変形例を示す縦断面図。

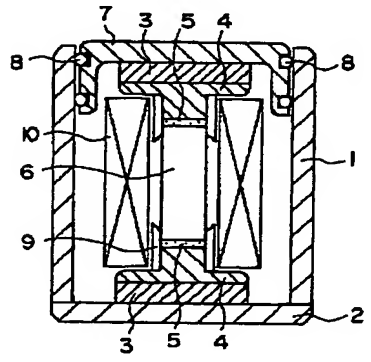
【図５】本発明に係る磁歪式振動子の他の変形例を示す縦断面図。

【図６】本発明に係る大変位用の磁歪式振動子を示す縦断面図。

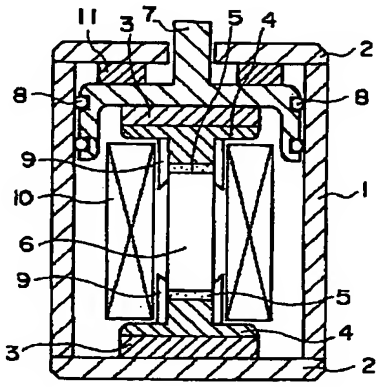
【符号の説明】

１…円筒型容器、２…固定部材、３…永久磁石、４…固定ヨーク、５…弾性体、６…磁歪ロッド、７…可動ヨーク、８…Ｏリング、９…ガイド、１０…空心コイル、１１…弾性体。

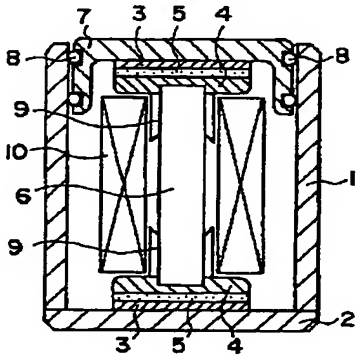
【図１】



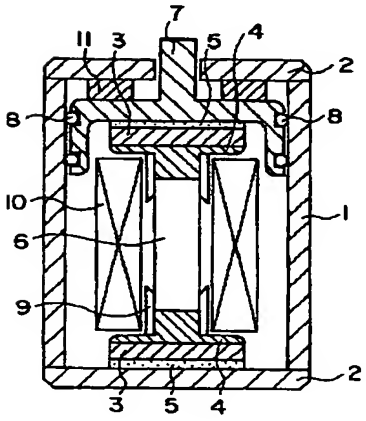
【図２】



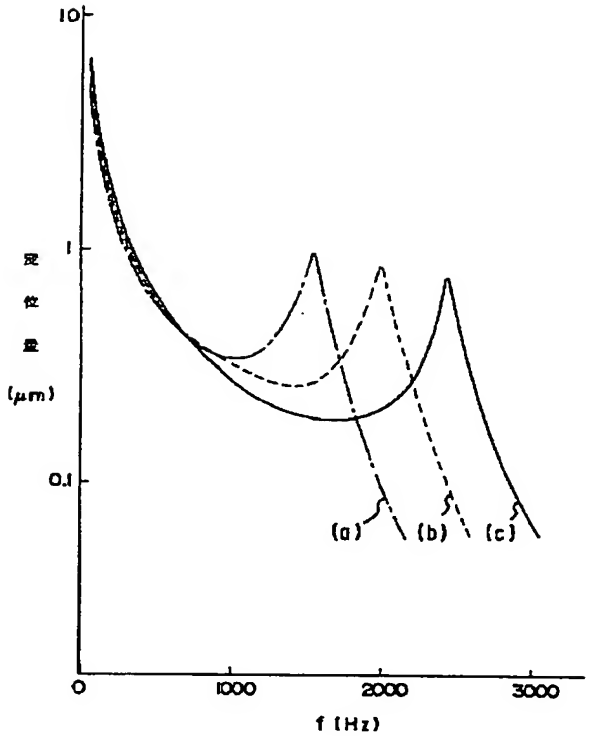
【図４】



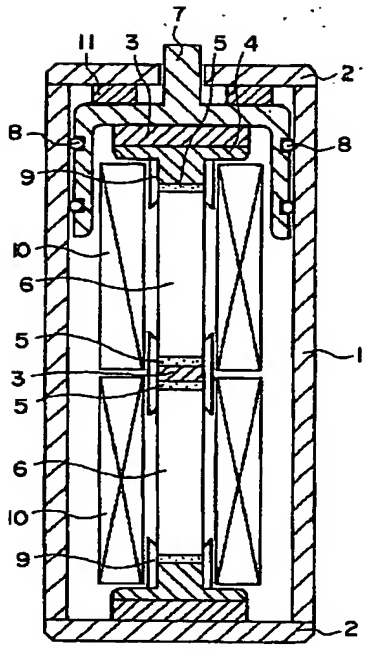
【図５】



【図３】


10
1
0.1
変位量
(μm)
0
1000
2000
3000
f (Hz)
(a)
(b)
(c)

【図６】


7
11
3
5
4
2
8
8
9
10
6
5
1
3
5
6
10
9
2